RIVER FLOW AND STRIPED BASS JAI

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Initial analyses by the Flow Committee in 1988 determined the relationship between the annual Juvenile Abundance Index (JAI) for striped bass and postimpoundment Roanoke River flow (1955-1987) as monitored by the USGS gage at Roanoke Rapids, North Carolina (Manooch and Rulifson 1989). A JAI value of 5 was selected by consensus of the original Recruitment Subcommittee as the cut-off between good and poor juvenile recruitment for the analyses.

Hassler et al. (1981) had concluded that abnormally high or low May River flows were detrimental to the formation of the year class, and the best JAI values were when May flows were moderately low to moderate (5,091-9,741 cfs). The Flow Committee analyzed the entire set of Hassler JAI values to confirm the relationship. Recruitment was best (JAI>5.0) for years in which River flows were low to moderate (5,000-11,000 cfs) and was poor (JAI<5.0) when flows were very low (3,900-8,100 cfs) or high (10,000 cfs or greater) during the spawning season. Additionally, the average flow pattern for good recruitment years (JAI>5.0) most closely resembled preimpoundment flow conditions. Details of the analyses were published in Rulifson and Manooch (1990a).

The average postimpoundment flow patterns for good year recruitment and poor year recruitment were modeled using a time series approach. Details of the analyses were published (Zincone and Rulifson 1991, see Appendix E). For this analysis, postimpoundment data included years from 1965 to 1986. Since it was the average seasonal flow patterns for the postconstruction period that were of interest, only River flow data after completion of Gaston Dam was used in the analysis. Seasonally, the full striped bass spawning window was used (1 march to 30 June) to include the prespawning, spawning, and postspawning periods. River flow data were subjected to time series analysis using the univariate Auto Regressive Integrated Moving Average (ARIMA) technique. The flow pattern in good recruitment years resembled a moderate plateau of discharge in March and early April, followed by a drop to a lower plateau (Figure 36). This pattern was similar to that determined for preimpoundment years (1912-1950, Figure 37). Instream flow in bad recruitment years remained higher throughout the four-month period and did not have the characteristic drop to the lower plateau (Figure 38).

Following the analyses described above, the Flow Committee recommended a River flow regime based on the preimpoundment flow patterns from 1 March to 30 June so that reservoir discharge would remain between the historical 25% and 75% quartiles of the daily flow (i.e., between the 25% low-flow value [Q_1] and 75% high flow value [Q_3] (Table 14). A modified flow regime from 1 April to 15 June was acceptable to the U.S. Army Corps of Engineers and Virginia Power Company because it did not require modification of the FERC license (Table 15).

This "Negotiated Flow Regime" was used in additional regression analyses to characterize patterns in postconstruction reservoir management. Briefly, the percentage of days during a season that reservoir discharge stayed within the historical (negotiated) Q_1-Q_3 bounds has decreased significantly over time, indicating that the manner in which the reservoir system is managed has changed throughout the years. Similarly, JAI values have declined with time, especially for the period 1978-1987, when the 10-year average was only 0.81. These analyses were presented in detail in the original report (Manooch and Rulifson 1989) and in the published article (Rulifson and Manooch 1990b, see Appendix D).

Additional analyses were performed to update and refine these earlier results. JAI and Q_1-Q_3 data sets for the period 1955-1990 were used in linear regression analyses to determine the

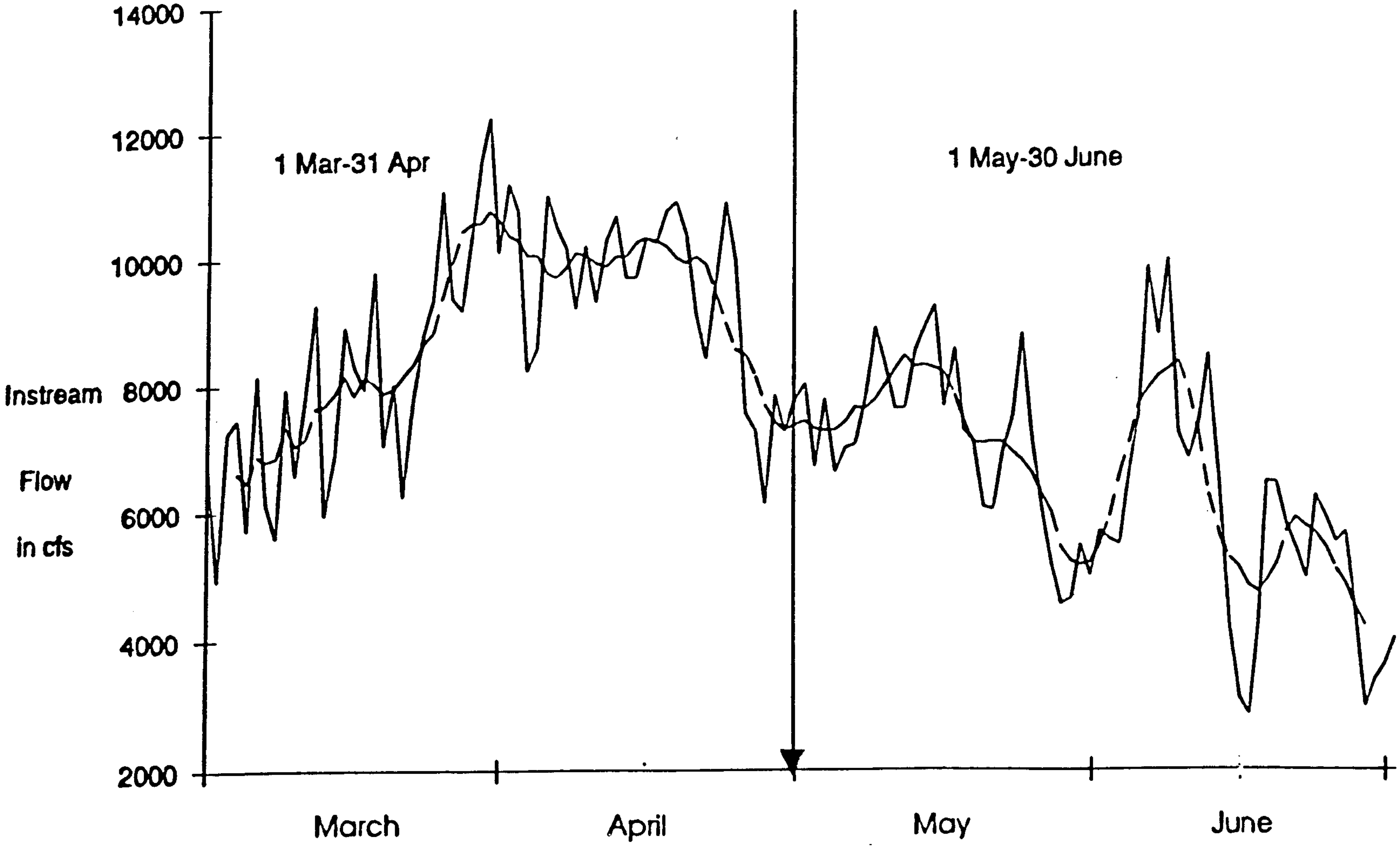

Figure 36. Roanoke River flow in postimpoundment years (1965-1986) exhibiting good striped bass recruitment (JAI>5.0). (Zincone and Rulifson 1991). The seven-day smoothed average is superimposed on a plot of trimmed means (see text).

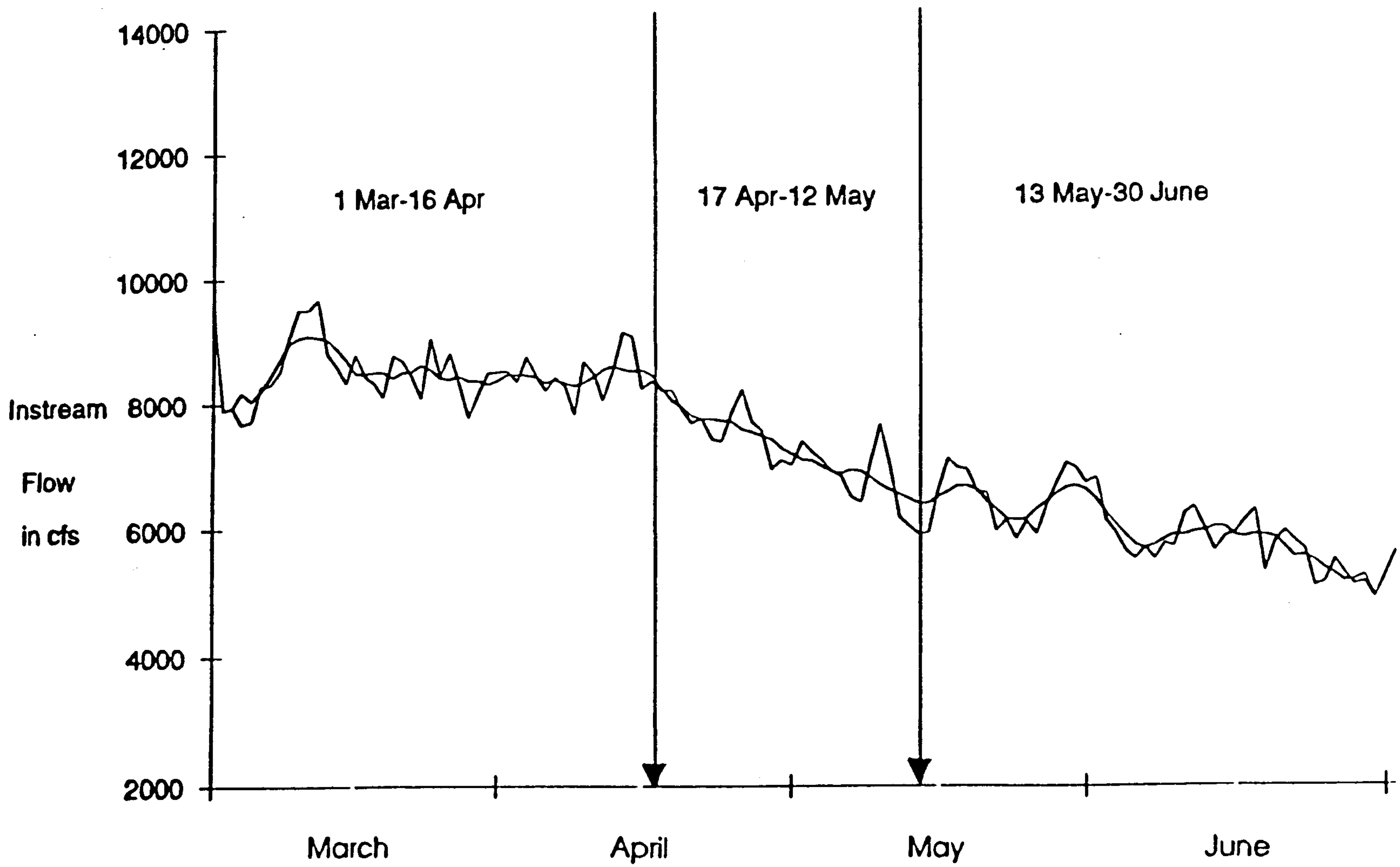

Figure 37. Time series analysis of preimpoundment flows (1912-1950) of the lower Roanoke River, NC (Zincone and Rulifson 1991). The seven-day smoothed average is superimposed on a plot of trimmed means (see text).

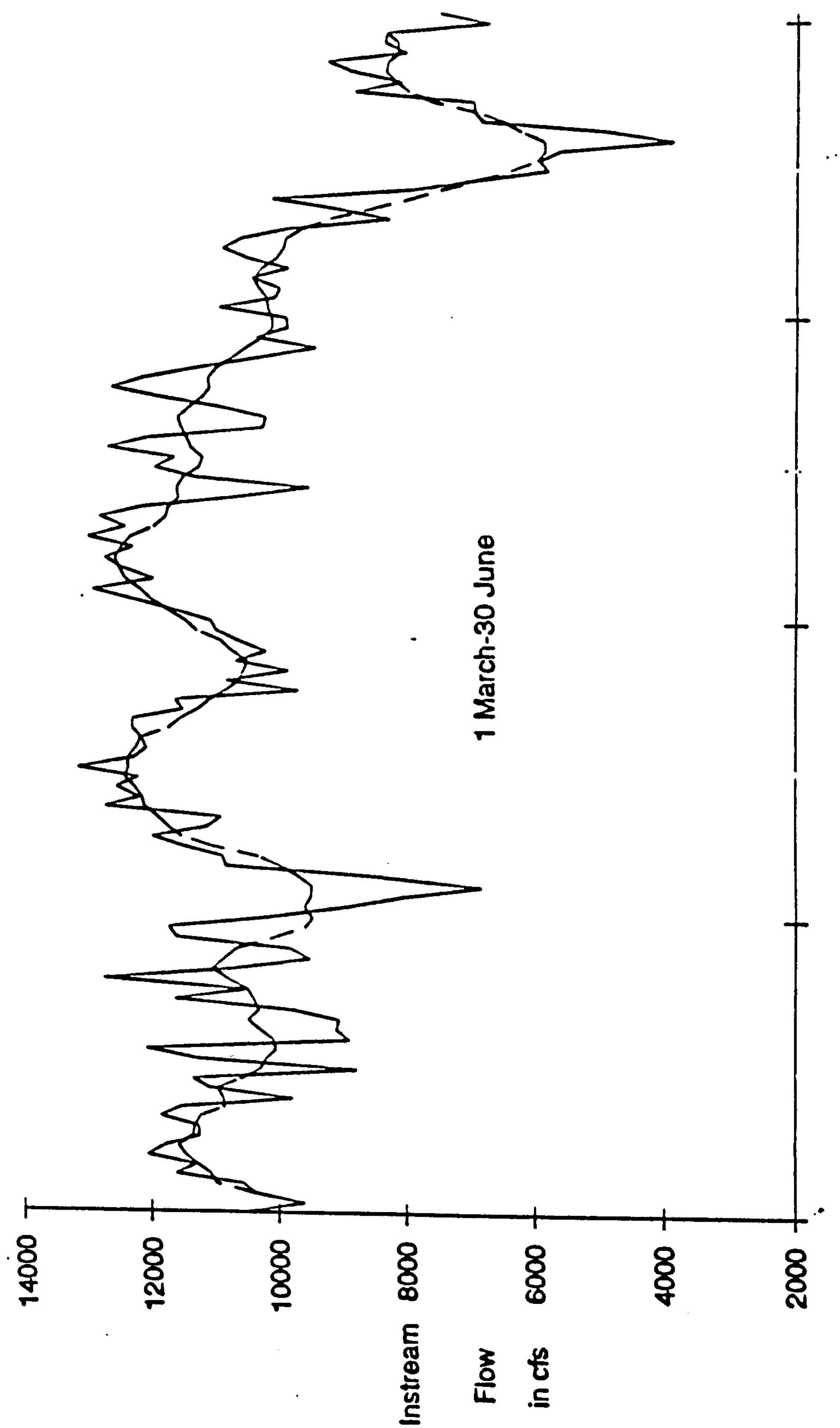

Figure 38. Roanoke River flow in postimpoundment years (1965-1986) exhibiting poor (JAI<5.0) striped bass recruitment (Zincone and Rulifson 1991). The seven-day smoothed average is superimposed on a plot of trimmed means (see text).

relationship between River flow and striped bass recruitment. River flow affects striped bass recruitment in California estuaries (Turner and Chadwick 1972, Stevens 1977), and white perch recruitment in portions of Chesapeake Bay (Summers et al. 1990). In our analysis, the JAI was estimated as a linear function of days within the Q_1-Q_3 bounds. The first analysis (full postimpoundment model) was performed on the original untransformed data set. A significant relationship between days within Q_1-Q_3 and JAI was established (df=1,34; F=9.977; P=0.0033; r^2=0.23, Table 35), but the residuals were not randomly distributed. The variance about the estimated regression increased with increases in both predicted JAI and observed days within Q_1-Q_3. In addition, there was an unusual pattern of negative residuals (i.e., the model overpredicted observed JAI) at the end of the time series.

To correct for this heterogeneity of variance, a second analysis was performed using data transformed to their natural logarithms. Again, a significant relationship between JAI and days within Q_1-Q_3 was established (df=1,34; F=28.891; P<0.0001; r^2=0.46, Table 35); however, the logarithmic model did not account for the unusual pattern of negative residuals at the end of the time series (Figure 39).

To accommodate the pattern of negative residuals, a third model was fitted which allowed for different intercepts and different slopes for the two periods 1955-1977, and 1978-1990 (Table 35). However, a direct test of parallelism in slopes was comfortably non-significant (P=0.66), meaning that the trend in both sets of data were similar, and that the differences could be corrected for by a different intercept. Thus, a fourth model with different intercepts only was fitted (Table 35), and a test of the difference between intercepts was highly significant (P=0.0004) (Figure 40). Residuals from this model were randomly distributed when plotted against LOGDAY values (Figure 41) and against years (Figure 42), thereby indicating that the model adequately describes the data.

The final equations for the fourth model (n=36, F=28.7, P>0.0001, R^2=0.63) were

1955-1977, LOGJAI = -3.4044 + 1.4657(LOGDAYS); and for

1978-1990, LOGJAI = -4.8706 + 1.4657(LOGDAYS).

In the logarithmic model the slope coefficient means that a 10% change in days within Q_1-Q_3 is associated with a 14.6% change in JAI. Further analyses of the influence of each observation on the predicted JAI and estimated slope coefficients suggested that years 1958 and 1986 were unusual years. Additional information is needed to determine why these years were unusual.

The model suggests that increasing the days within the Q_1-Q_3 bounds would result in an increase in juvenile abundance. Of course, this prediction applies only to the observed range of data. The need for two intercepts to describe the data indicates that some significant phenomenon occurred around 1977 to influence the striped bass spawning-river flow relationship.

Table 35. Results of ANOVA to determine the relationship between of Roanoke River flow (1955-1990) and the striped bass Juvenile Abundance Index (JAI). DAYSWIN = the number of days in which the instream flow measured at the USGS gage (Roanoke Rapids) was within the Q_1-Q_3 bounds. Standard errors appear in parenthesis below the estimated intercepts and slopes.

Independent Variable	Dependent Variable	Dummy Variable or Years	Estimated Intercept	Estimated Slope	Mean Square Error	DF	F	Prob>F	R^2
DAYSWIN	JAI	none	-1.3900 (2.3729)	0.2251 (0.0712)	30.2211	1,34	9.977	0.0033	0.23
LOGDAYS	LOGJAI	none	-5.7677 (1.2591)	2.0195 (0.3757)	1.3529	1,34	28.891	0.0001	0.46
LOGDAYS	LOGJAI	Dummy for 1955-77	-3.8974[a] (1.6078)	1.6078[a] (0.4712)	18.065	3,32	18.713	0.0001	0.64
LOGDAYS	JAI	Dummy for 1978-90	-0.4608[a] (2.2836)	-0.3111[a] (0.6971)					
LOGDAYS	LOGJAI	1955-77	-3.4044[a] (1.2068)	1.4657[a] (0.3430)	27.0014	2,33	28.666	0.0001	0.63
LOGDAYS	LOGJAI	Dummy for 1978-90	-1.4662[a] (0.3685)						

[a]Values reported are actually the difference in intercept and slope, respectively, between the 1955-1977 data and the 1978-1990 data.

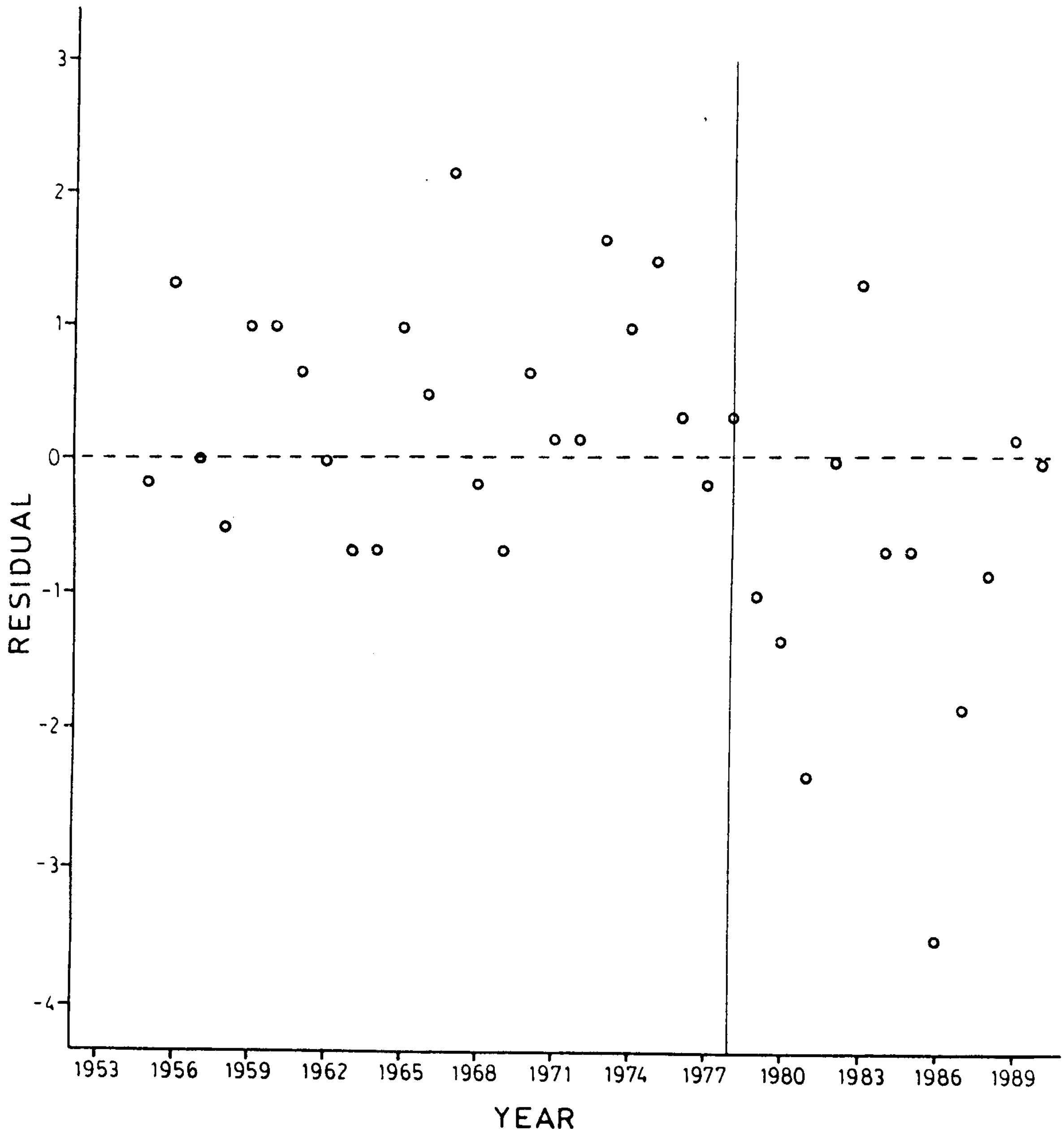

Figure 39. Plot of the residuals from the full model analysis (1955-1990) depicting the relationship of Roanoke River flow and striped bass recruitment in Albemarle Sound.

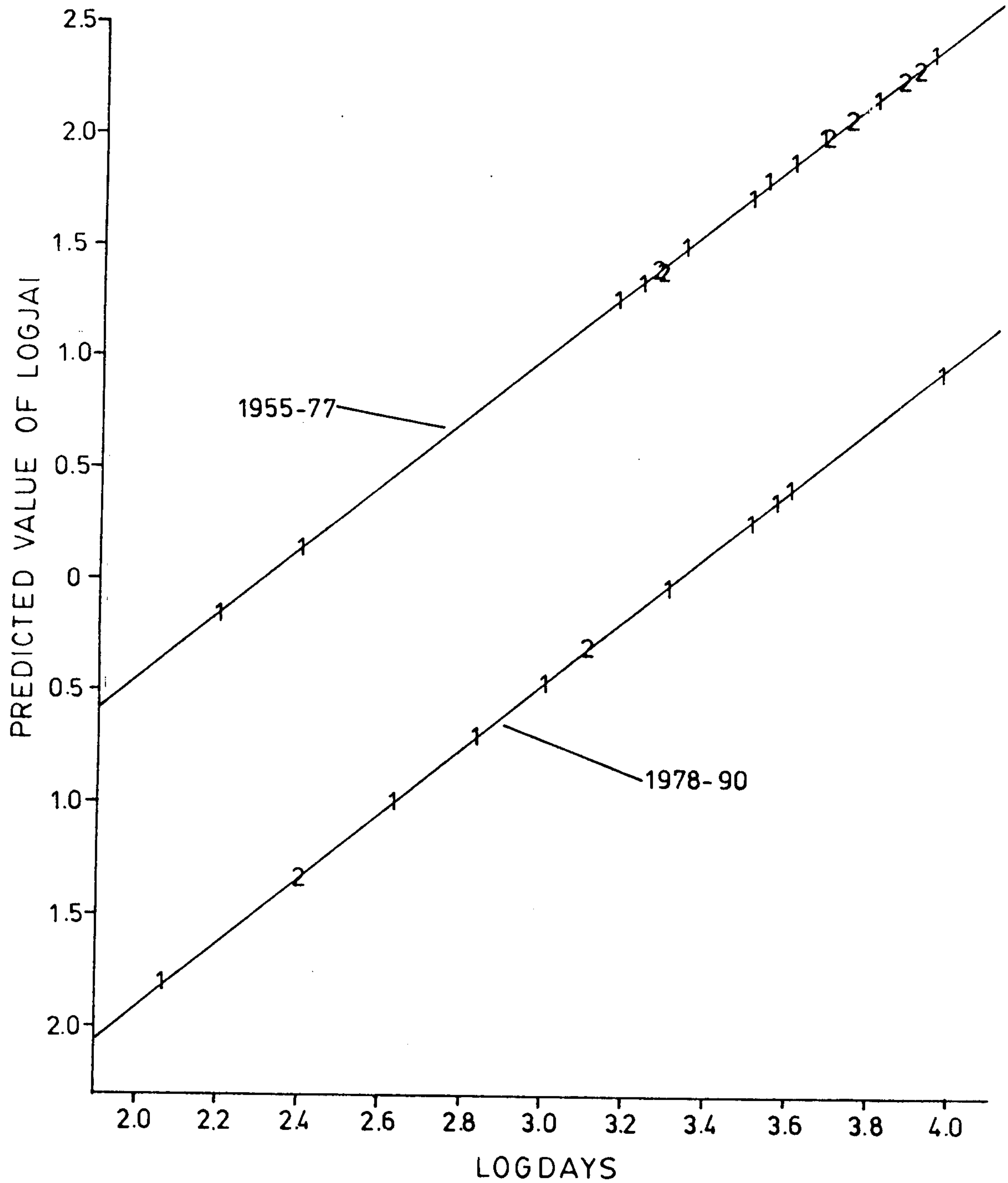

Figure 40. Full model (1955-1990) depicting the relationship between Roanoke River flow (days within Q_1-Q_3) and striped bass recruitment in Albemarle Sound.

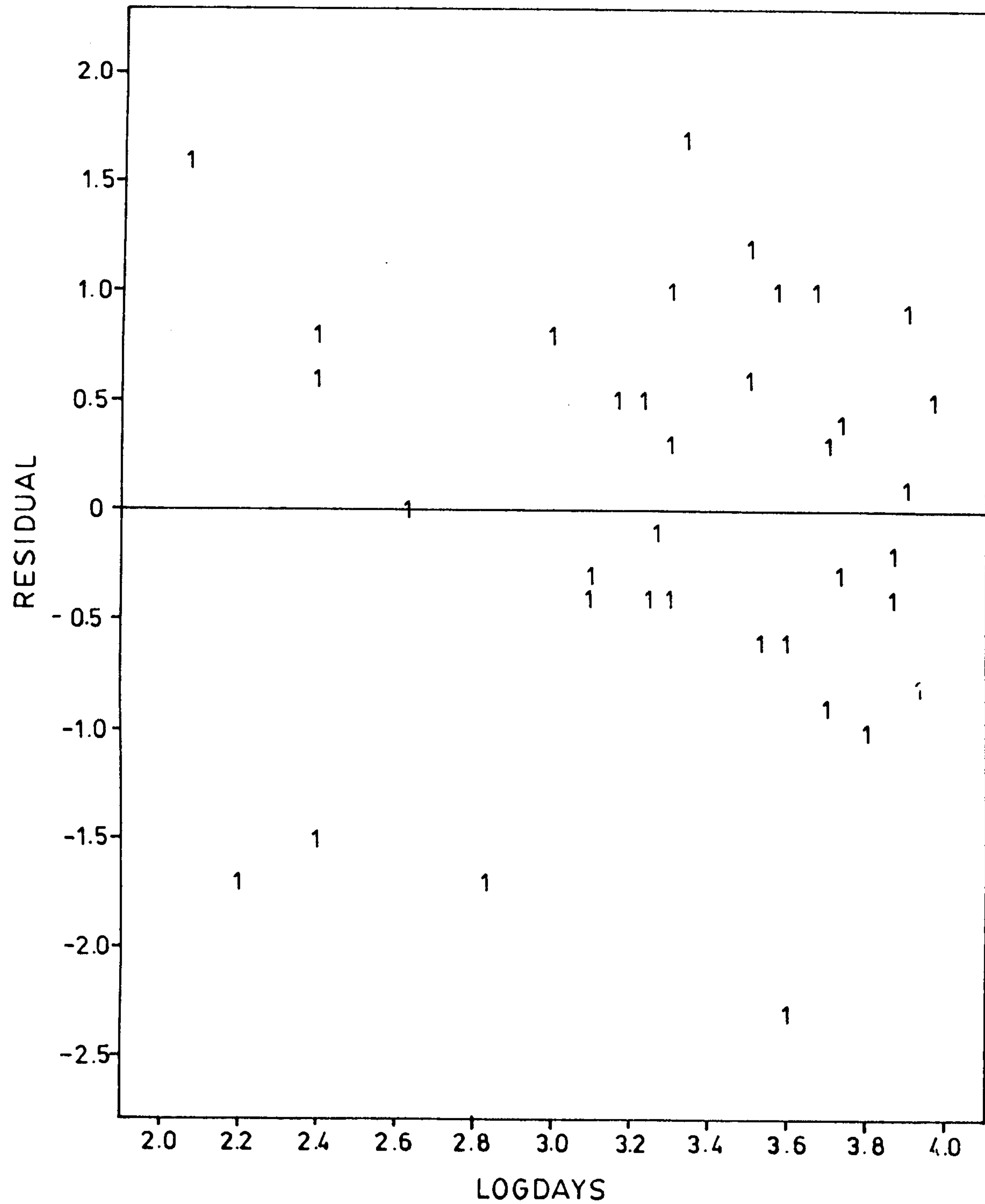

Figure 41. Plot of the natural log-transformed data analysis (1955-1990) showing the random distribution of the residuals against the logdays within Q_1-Q_3.

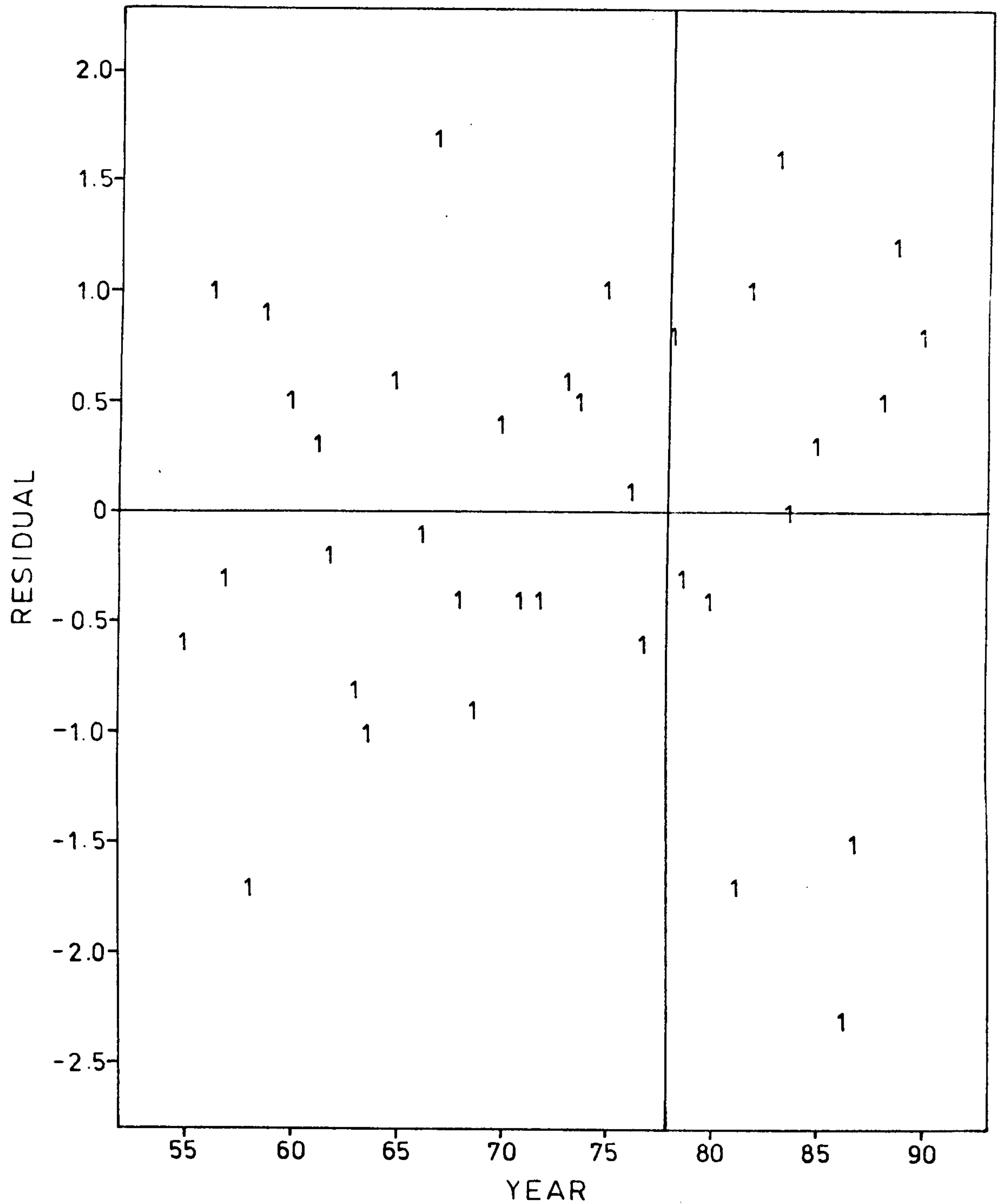

Figure 42. Plot of the natural log-transformed data analysis (1955-1990) showing the random distribution of the residuals against postimpoundment years.